Chapter 5. Macrobenthic Communities

INTRODUCTION

Benthic macroinvertebrates along the coastal shelf of southern California represent a diverse faunal community that is important to the marine ecosystem (Fauchald and Jones 1979, Thompson et al. 1993a, Bergen et al. 2001). These animals serve vital ecological functions in wide ranging capacities (Snelgrove et al. 1997). For example, some species decompose organic material as a crucial step in nutrient cycling; other species filter suspended particles from the water column, thus affecting water clarity. Many species of benthic macrofauna also are essential prey for fish and other organisms.

Human activities that impact the benthos can sometimes result in toxic contamination, oxygen depletion, nutrient loading, or other forms of environmental degradation. Certain macrofaunal species are sensitive to such changes and rarely occur in impacted areas, while others are opportunistic and can persist under altered conditions (Gray 1979). Because various species respond differently to environmental stress, monitoring macrobenthic assemblages can help to identify anthropogenic impact (Pearson and Rosenberg 1978, Bilyard 1987, Warwick 1993, Smith et al. 2001). Also, since many animals in these assemblages are relatively stationary and long-lived, they can integrate the effects of local environmental stressors (e.g., pollution or disturbance) over time (Hartley 1982, Bilyard 1987). Consequently, the assessment of benthic community structure is a major component of many marine monitoring programs, which are often designed to document both existing conditions and trends over time.

Overall, the structure of benthic communities may be influenced by many factors including depth, sediment composition and quality (e.g., grain size distribution, contaminant concentrations), oceanographic conditions (e.g., temperature, salinity, dissolved oxygen, ocean currents), and biological factors (e.g., food availability, competition, predation). For example, benthic assemblages on the coastal shelf of southern California typically vary along sediment particle size and/or depth gradients (Bergen et al. 2001). Therefore, in order to determine whether changes in community structure are related to human impacts, it is necessary to have an understanding of background or reference conditions for an area. Such information is available for the monitoring area surrounding the South Bay Ocean Outfall (SBOO) and the San Diego region in general (see City of San Diego 1999, 2010, Ranasinghe et al. 2003, 2007).

This chapter presents analyses and interpretations of the macrofaunal data collected in 2010 at fixed stations surrounding the SBOO, including comparisons of the different soft-bottom macrofaunal assemblages in the region and descriptions of benthic community structure. The primary goals are to: (1) identify possible effects of wastewater discharge on local macrofaunal communities, (2) determine the presence or absence of biological impacts near the discharge site, and (3) identify any spatial or temporal trends in benthic community structure in the region.

MATERIALS AND METHODS

Collection and Processing of Samples

Samples of benthic macroinvertebrates were collected at 27 established stations surrounding the SBOO located along the 19, 28, 38, or 55-m depth contours during January and July 2010 (Figure 5.1). Four of these stations are considered to represent "nearfield" conditions (i.e., I12, I14, I15, I16) and are located less than 1000 m from the wye or diffuser legs in order to assess possible ecosystem impacts to the area immediately adjacent the outfall. All other stations are referred to as "farfield."

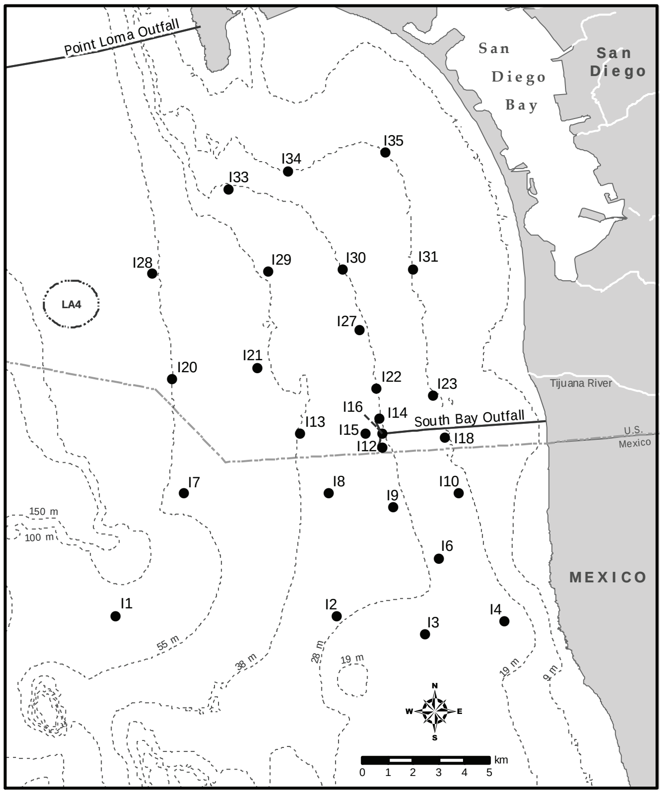

Figure 5.1
Benthic station locations sampled for the South Bay Ocean Outfall Monitoring Program.

Two replicate samples for benthic community analyses were collected per station during each survey using a double 0.1-m^2 Van Veen grab. One of the two grabs from the first cast was used for macrofauna, while the adjacent grab was used for sediment quality analysis (see Chapter 4); a second grab for macrofauna was then collected from a subsequent cast. To ensure consistency of grab samples, criteria established by the United States Environmental Protection Agency (USEPA) were followed to standardize sample disturbance and depth of penetration (USEPA 1987). All samples were sieved aboard ship through a 1.0-mm mesh screen, and organisms retained on the screen were collected and relaxed for 30 minutes in a magnesium sulfate solution before fixing in buffered formalin. After a minimum of 72 hours, each sample was rinsed with fresh water and transferred to 70% ethanol. All animals were sorted from the debris into major taxonomic groups by a subcontracted laboratory and then identified to species or the lowest taxon possible and enumerated by City of San Diego marine biologists.

Data Analyses

The following community structure parameters were calculated and summarized for each station per 0.1-m^2 grab: species richness (number of species), abundance (number of individuals), Shannon diversity index (H'), Pielou's evenness index (J'), Swartz dominance (minimum number of taxa whose combined abundance accounts for 75% of the individuals in a sample; Swartz et al. 1986, Ferraro et al. 1994), and the benthic response index (BRI) of Smith et al. (2001). Additionally, the total or cumulative number of species over all grabs was calculated for each station.

To examine spatio-temporal patterns in the overall similarity of benthic macrofaunal assemblages, analyses were performed on grab-averaged data using PRIMER software (Clarke 1993, Warwick 1993, Clarke and Gorley 2006). These analyses included classification (cluster analysis) by hierarchical agglomerative clustering with group-average linking and ordination by non-metric multidimensional scaling (nMDS). Species abundance data were square-root transformed and the Bray-Curtis measure of similarity was used as the basis for classification. Similarity profile (SIMPROF) analysis was used to confirm non-random structure of the dendrogram (Clarke et al. 2008). Similarity percentages (SIMPER) analysis was used to identify which species accounted for differences between cluster groups as well as the specific species that typified each cluster group. Patterns in the distribution of the different assemblages were compared to environmental variables by overlaying the physico-chemical data onto nMDS plots based on the biotic data (Field et al. 1982, Clarke and Ainsworth 1993).

Results

Community Parameters

Species richness

A total of 736 taxa (mostly species) were identified during the 2010 SBOO surveys. Of these, 190 (~26%)

Table 5.1

Summary of macrofaunal community parameters for SBOO benthic stations sampled during 2010. Tot Spp = cumulative no. species for the year; SR = species richness (no. species/0.1 m^2); Abun = abundance (no. individuals/0.1 m^2); H' = Shannon diversity index; J' = evenness; Dom = Swartz dominance; BRI = benthic response index; * = nearfield stations. Data are expressed as annual means (n = 4) except Tot Spp (n = 1).

Station		Depth	Tot Spp	SR	Abun	H'	J'	Dom	BRI
19-m Stations									
I35		19	150	78	290	3.8	0.88	28	29
I34		19	91	37	470	1.7	0.48	5	9
I31		19	141	61	251	2.8	0.69	14	20
I23		21	178	75	233	3.7	0.86	27	21
I18		19	119	55	280	2.7	0.66	11	20
I10		19	127	54	185	3.1	0.78	17	19
I4		18	112	41	157	3.0	0.81	14	7
28-m Stations									
I33		30	163	82	318	3.6	0.82	25	24
I30		28	157	73	247	3.7	0.86	27	23
I27		28	145	65	184	3.5	0.85	25	23
I22		28	209	93	751	3.0	0.64	22	22
I14*		28	161	75	301	3.2	0.75	21	24
I16*		28	180	82	366	3.1	0.69	21	25
I15*		31	135	58	996	1.3	0.31	2	18
I12*		28	207	86	648	2.7	0.59	15	23
I9		29	204	99	418	3.8	0.84	30	22
I6		26	107	49	1490	1.5	0.39	5	10
I2		32	84	38	199	2.3	0.64	7	15
I3		27	90	38	213	2.6	0.73	10	9
38-m Stations									
I29		38	242	124	474	4.1	0.84	39	19
I21		41	121	55	222	3.3	0.83	17	8
I13		38	118	48	152	3.1	0.81	17	9
I8		36	117	51	343	2.4	0.62	8	20
55-m Stations									
I28		55	295	148	485	4.5	0.90	56	13
I20		55	137	57	219	3.2	0.81	17	5
I7		52	124	53	136	3.5	0.89	21	7
I1		60	155	74	237	3.7	0.85	27	12
	Mean		151	68	380	3.1	0.73	19	16
All Grabs	Standard Error		9	3	40	0.1	0.02	1	1
	Minimum		84	22	58	0.5	0.12	1	1
	Maximum		295	163	3216	4.6	0.93	60	31

represented rare taxa that were recorded only once. Mean values of species richness ranged from a low of 37 taxa per 0.1 m^2 at station I34 to a high of 148 taxa per 0.1 m^2 at station I28 (Table 5.1). Overall species richness dropped compared to last year, with 10% fewer taxa collected in 2010 versus 2009. Although species richness varied spatially, there were no apparent patterns relative to distance from the discharge site (Table 5.1, Figure 5.2A).

Macrofaunal abundance

A total of 41,051 macrofaunal individuals were identified in 2010, with mean abundance values ranging from 136 to 1490 animals per 0.1 m^2 (Table 5.1). The greatest number of animals occurred at station I6, while the fewest animals occurred at station I7. Overall, there was a 7% increase in total macrofaunal abundance

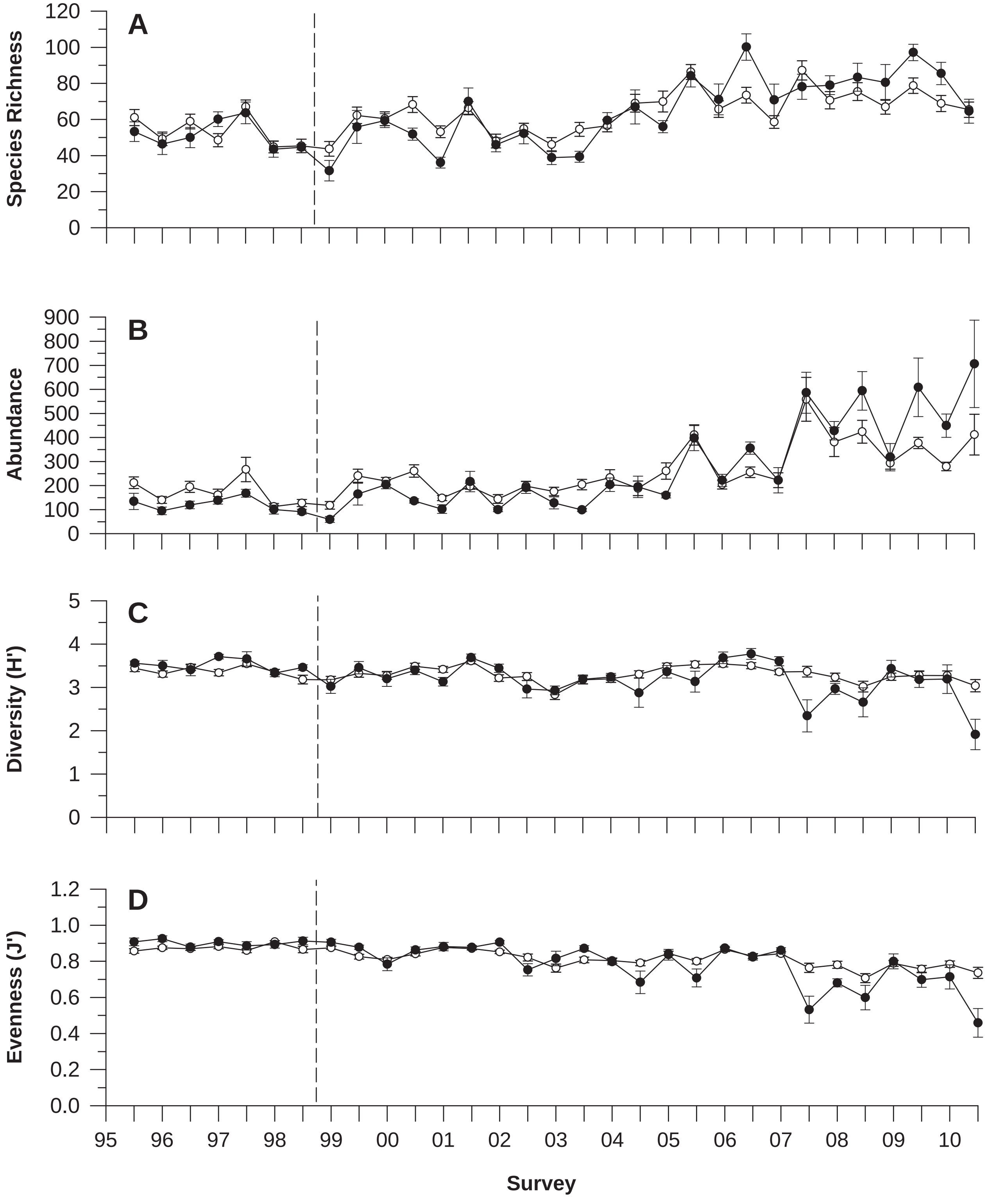

Figure 5.2

Macrofaunal community parameters at SBOO benthic stations from 1995 to 2010. Parameters include: Species richness (no. of taxa); Abundance (no. of animals); Diversity = H'; Evenness = J'; Swartz dominance index; BRI = Benthic response index. Data are expressed as means ± standard error per 0.1 m^2 pooled over nearfield stations (filled circles; $n = 8$) versus farfield stations (open circles; $n = 46$) for each survey. Dashed line indicates onset of discharge from the SBOO.

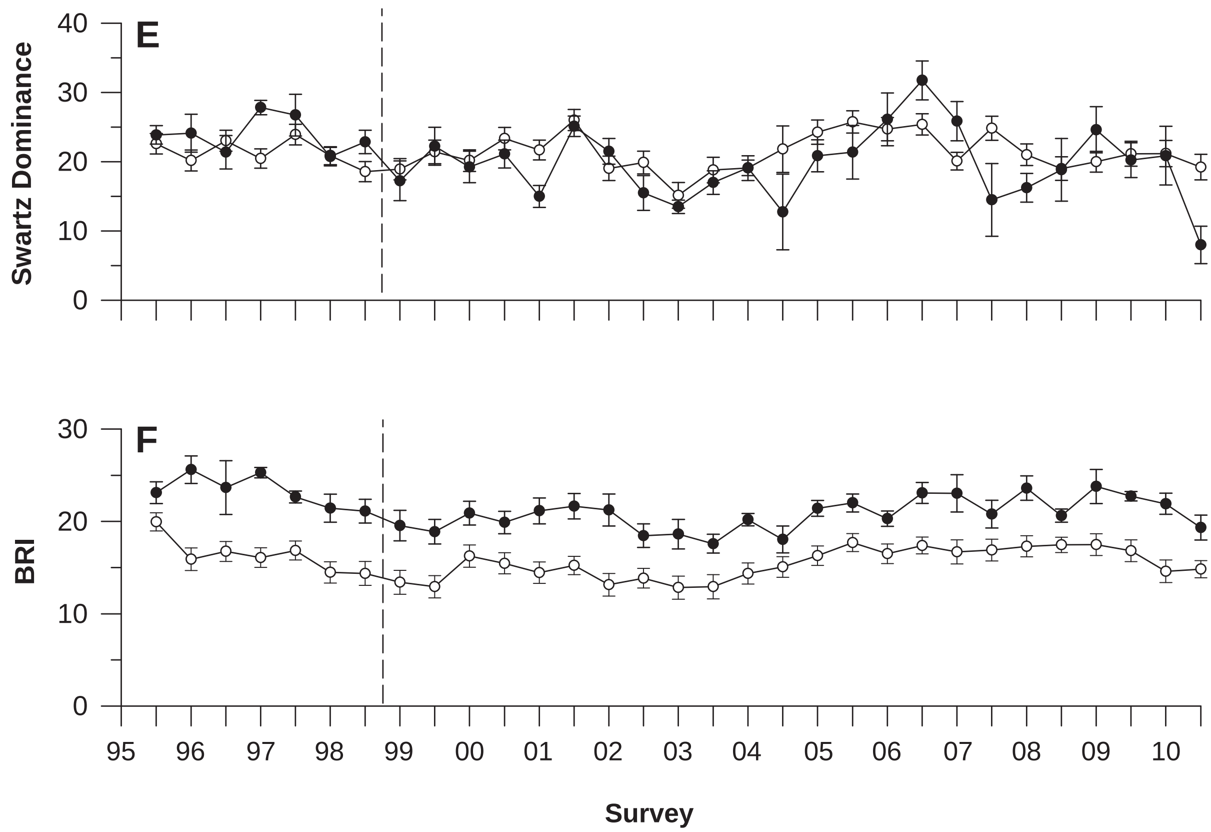

Figure 5.2 *continued*

between 2009 and 2010 (Figure 5.2B), with the greatest change occurring at station I6 (City of San Diego 2010). The mean abundance for all nearfield stations has increased in recent years relative to farfield stations (Figure 5.2B). In 2010, the increased nearfield abundance and associated variation relative to farfield stations was likely due to large numbers of *Spiophanes norrisi* collected at stations I12 and I15 in July.

Species diversity and dominance

Average species diversity (H') ranged from 1.3 at station I15 to 4.5 at station I28 during 2010 (Table 5.1). Historically, H' values have mostly been similar between nearfield and farfield stations. However, average H' values at nearfield stations sampled in July 2010 were low compared to farfield stations (1.9 vs. 3.0, respectively) (Figure 5.2C). Evenness (J') compliments diversity, with higher J' values (on a scale of 0–1) indicating that species are more evenly distributed (i.e., not dominated by a few highly abundant species). During 2010, J' values averaged between 0.31 at station I15 and 0.90 at station I28 with spatial patterns similar to those for diversity (Figures 5.2C, D). Swartz dominance values averaged from 2 to 56 species per station during the year (Table 5.1). This range reflects the dominance of a few species at some sites (e.g., low values at stations I15, I6, and I34) versus other stations where many taxa contributed to the overall abundance (e.g., high values at stations I28 and I29).

Benthic response index

Benthic response index (BRI) values in 2010 averaged from 5 at station I20 to 29 at station I35, while BRI values for individual grabs ranged from 1 to 31 (Table 5.1). BRI values below 25 are considered indicative of reference conditions, while values between 25–34 represent “a minor deviation from reference conditions” that should be confirmed by additional sampling (Smith et al. 2001). Station I35 was the only station with an annual mean BRI value above 25. This station, located on the 19-m depth contour near the mouth of the San Diego Bay, had an annual mean BRI value of 31 in 2009. All nearfield stations had annual BRI means at or below 25 in

Table 5.2

Percent composition of species and abundance by major taxonomic group (phylum) for SBOO benthic stations sampled during 2010. Data are expressed as annual means (range) for all stations combined; $n = 27$.

Phyla	Species (%)	Abundance (%)
Annelida (Polychaeta)	48 (38–58)	72 (55–95)
Arthropoda (Crustacea)	21 (14–27)	12 (2–23)
Mollusca	16 (10–24)	8 (1–18)
Echinodermata	6 (2–11)	4 (1–11)
Other Phyla	9 (6–13)	4 (1–9)

2010. Along with I35, three other stations contained individual grabs with BRI values >25 (I16, I27, and I30). As in previous years (including the pre-discharge period), mean BRI values at the four nearfield stations were higher than mean values for all the farfield stations combined (Figure 5.2F).

Dominant Species

Macrofaunal communities in the SBOO region were dominated by polychaete worms in 2010, which accounted for 48% of all species collected (Table 5.2). Crustaceans accounted for 21% of species reported, while molluscs, echinoderms, and all other taxa combined accounted for the remaining 16%, 6%, and 9%, respectively. Polychaetes were also the most numerous animals, accounting for 72% of the total abundance. Crustaceans accounted for 12% of the animals collected, molluscs 8%, echinoderms 4%, and the remaining phyla 4%. Overall, the above distributions were very similar to those observed in 2009 (City of San Diego 2010).

Seven polychaetes (i.e., *Spiophanes norrisi* and *S. duplex*, Euclymeninae sp A, *Monticellina siblina*, *Scoloplos armiger* complex, *Onuphis* sp A, and *Sigalion spinosus*) and three crustaceans (i.e., *Ampelisca cristata cristata*, *Euphilomedes carcharodonta*, and *Foxiphalus obtusidens*) were among the 10 most abundant macroinvertebrates sampled during the year (Table 5.3). The most abundant species collected was the spionid *S. norrisi*, which occurred at 98% of the stations and averaged 162 individuals per sample. While *S. norrisi* was nearly ubiquitous in distribution, abundances at individual stations varied considerably (range: 6–2504). For example, five stations (I6, I15, I22, I34 and I12 in July) supported much higher abundances of this species than the other sites, with a combined total of 11,536 individuals. Overall, *S. norrisi* accounted for about 43% of the macrobenthic fauna sampled during 2010 and has become the most abundant species collected since monitoring began (Figure 5.3, Appendix D.1).

Few other macrobenthic species were as widely distributed as *S. norrisi* (Table 5.3), with only seven taxa occurring in at least 80% of the samples. However, many of the species collected in 2010 have been dominant in past years as well. For example, six of the most abundant species collected in 2010 (i.e., *S. norrisi*, *A. cristata cristata*, *S. duplex*, *E. carcharodonta*, Euclymeninae sp A, and *M. siblina*) were among the 10 most abundant taxa collected historically (Figure 5.3; Appendix D.1). In contrast, some species were found in relatively high abundances at a limited number of stations. For example, the oweniid polychaete *Myriochele gracilis* was collected at only two stations (I1 and I28) with mean abundances of 29 animals per 0.1 m^2 grab.

Classification of Macrobenthic Assemblages

Results of the ordination and cluster analyses discriminated six habitat-related macrobenthic assemblages (Figure 5.4). These assemblages (cluster groups A–F) varied in terms of species composition (i.e., specific taxa present) and the relative abundance of each species, and occurred at sites separated by different depths and/or sediment microhabitats (Figure 5.5). The SIMPROF procedure indicated statistically significant non-random structure among samples (Global test: $\pi = 6.82$, $p < 0.001$), and an nMDS ordination of the station/survey entities supported the validity of

Table 5.3

The 10 most abundant macroinvertebrates collected at the SBOO benthic stations during 2010. Abundance values are expressed as mean number of individuals per 0.1-m^2. Percent occurrence = percent of total samples where the species was collected.

Species	Higher Taxa	Abundance per Sample	Percent Occurrence
Spiophanes norrisi	Polychaeta: Spionidae	162.0	98
Spiophanes duplex	Polychaeta: Spionidae	9.9	80
Euclymeninae sp A	Polychaeta: Maldanidae	9.6	74
Monticellina siblina	Polychaeta: Cirratulidae	8.7	72
Scoloplos armiger complex	Polychaeta: Orbiniidae	2.7	91
Ampelisca cristata cristata	Crustacea: Amphipoda	2.4	82
Euphilomedes carcharodonta	Crustacea: Ostracoda	2.1	80
Onuphis sp A	Polychaeta: Onuphidae	1.8	80
Sigalion spinosus	Polychaeta: Sigalionidae	1.5	82
Foxiphalus obtusidens	Crustacea: Amphipoda	1.5	78

the selected cluster groups (Figure 5.4B). SIMPER analysis identified species that were characteristic, though not always the most abundant, within assemblages; a comparison of the most abundant taxa for each cluster group combined with SIMPER results is indicated in Table 5.4. A list of species identified by SIMPER as discriminating between individual cluster groups can be found in Appendix D.2. Overall, clusters were very similar and no single species strongly discriminated between groups. On average, 177 species contributed to 75% of the dissimilarity between any two cluster groups.

Cluster group A contains macrofaunal assemblages sampled in January and July at two stations located east of the outfall discharge site along the 55-m depth contour. This group of sites averaged 176 individuals and 55 taxa per 0.1 m^2. The three most characteristic species encountered were the ophiuroid *Ophiuroconis bispinosa*, the isopod *Eurydice caudata*, and the sabellid polychaete *Jasmineira* sp B. Sediments at these sites were coarse, composed of red relict sands with only 2% fines and had a total organic carbon (TOC) concentration of 0.1% weight (% wt).

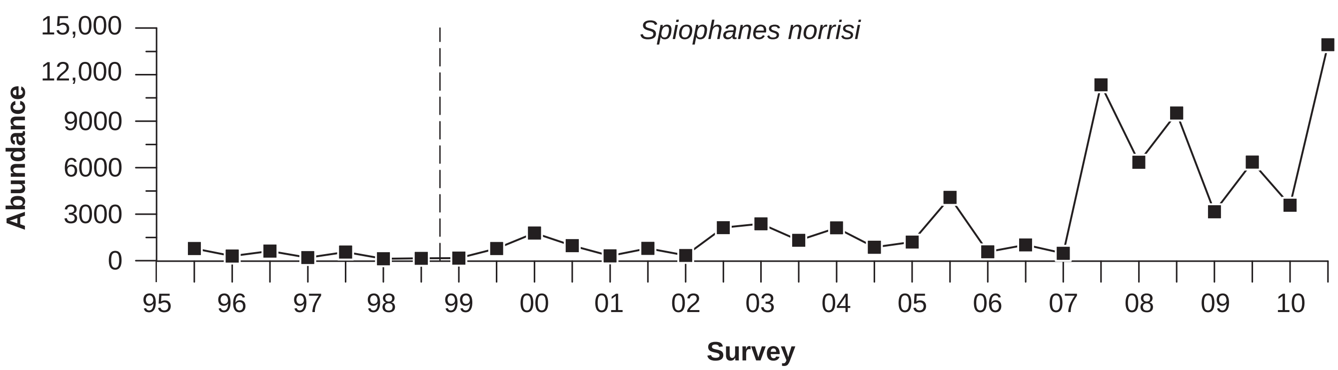

Figure 5.3

Total abundance per survey for *Spiophanes norrisi* at the SBOO benthic stations from 1995–2010. Dashed line indicates onset of wastewater discharge.

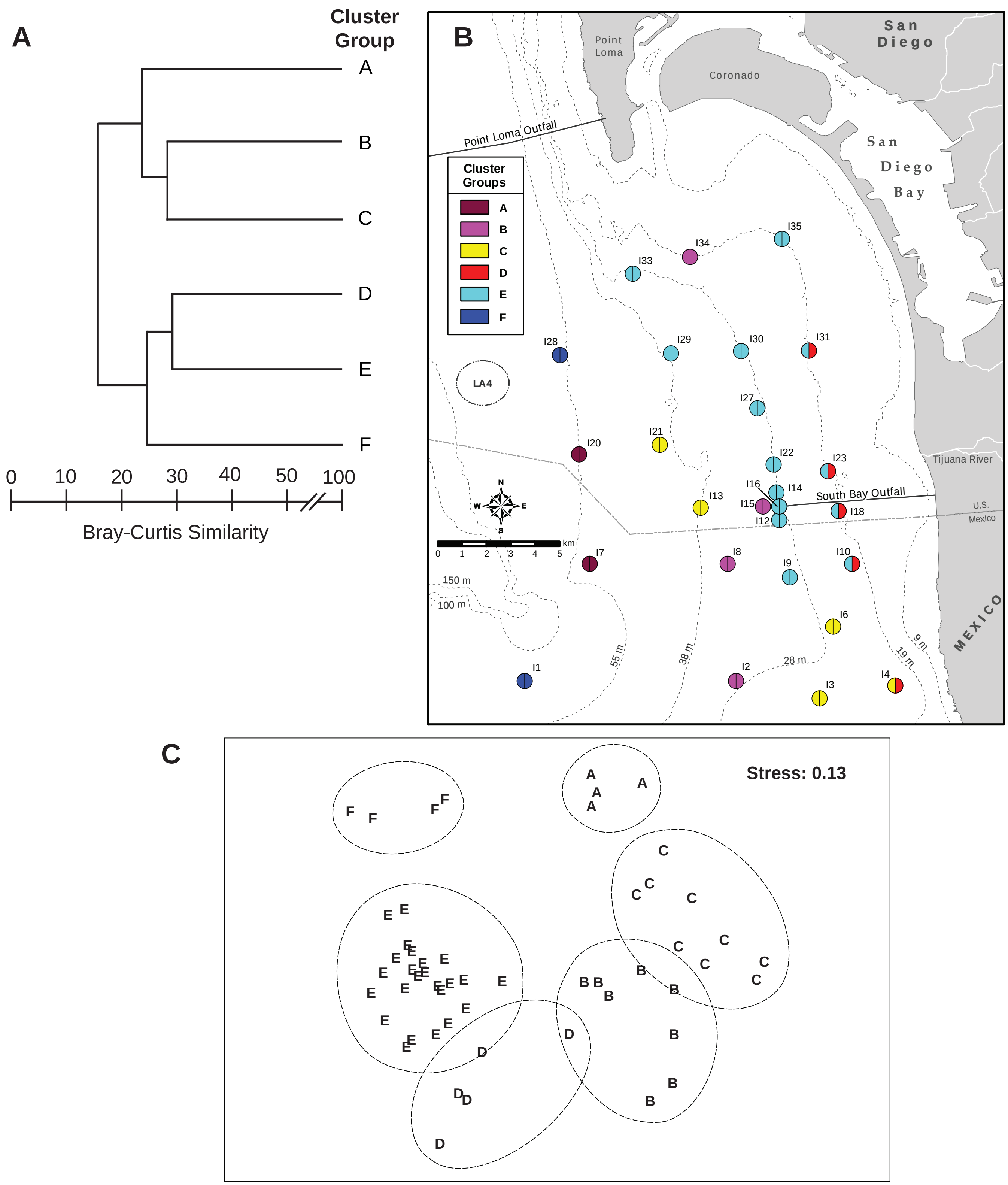

Figure 5.4

Results of multivariate analyses of macrofaunal abundance data for the SBOO benthic stations sampled during January and July 2010. Data are presented as: (A) cluster results; (B) spatial distribution of macrobenthic assemblages delineated by ordination and classification analyses (left half of circle represents cluster group affiliation for the January survey; right half represents the July survey); (C) nMDS ordination based on square-root transformed abundance data for each station/survey entity. Dashed ellipses enclose cluster groups within a similarity of 29.5%.

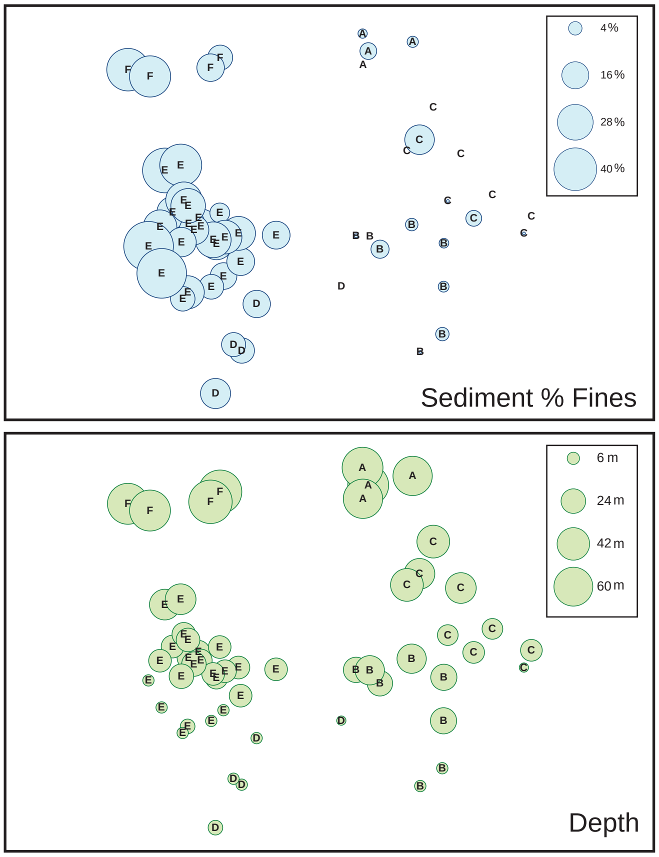

Figure 5.5
Ordination (nMDS) of SBOO benthic stations sampled during winter and summer 2010. Cluster groups A–F are superimposed on station/surveys. Percentages of fine particles in the sediments and station depth are further superimposed as circles that vary in size according to the magnitude of each value. Plots indicate associations of benthic assemblages with habitats that differ in sediment grain size and depth. Stress = 0.13.

Cluster group B contains shallow-shelf macrofaunal assemblages that typically occurred between the 28 and 38-m depth contours. Sites in this group averaged 46 taxa and 502 individuals per 0.1 m^2, the latter being the highest abundance among all cluster groups. The glycerid polychaete *Glycera oxycephala* was characteristic, as were the orbiniid polychaete *Scoloplos armiger* and the sand dollar *Dendraster terminalis*. The sediments associated with this assemblage were mostly sand with some shell hash and 1% fines, and with TOC values of 0.1% wt on average.

Cluster group C (five sites) includes assemblages that occurred mostly south or east of the outfall at depths between 19–38 m. These assemblages averaged 45 taxa and 472 organisms per 0.1 m^2. *Scoloplos armiger*, *Dendraster terminalis* and the spionid polychaete *Spio maculata* were the three most characteristic species found at these sites. The habitat was characterized by mixed but coarse sediments, especially red relict sand, with TOC values that averaged 0.1% wt.

Cluster group D represents macrofaunal assemblages from the shallowest sites sampled during the July survey that occurred along the 19-m depth contour. Abundance averaged 219 individuals and species richness averaged 54 taxa per 0.1 m^2. The three most characteristic species included the amphipod *Ampelisca cristata cristata*, the ampharetid polychaete *Ampharete labrops*, and the nemertean *Carinoma mutabilis*. Sediments at this site were relatively sandy with 8% fines and contained shell hash and organic debris. These sediments had an average TOC value of 0.1% wt.

Cluster group E contains macrobenthic assemblages from fourteen stations located along the 19 and 28-m depth contours, and represents the most geographically broad subset of sites found in any of the clusters. This shallow shelf assemblage averaged 83 taxa and 376 individuals per 0.1 m^2, with the bivalve *Tellina modesta*, the spionid *Spiophanes berkeleyorum*, and the maldanid Euclymeninae sp A being the most characteristic species recorded. The sediments associated with this assemblage were characterized by sand, some organic debris, and 14% fines with TOC values of 0.2% wt on average.

Cluster group F includes mid-shelf assemblages from two stations located near the 55-m depth contour, which bracket the sites in cluster group A. These sites averaged 361 individuals and 111 taxa per 0.1 m^2, the latter representing the highest species richness for the region. The three most characteristic species included the paronid polychaete *Aricidea* (*Acmira*) *simplex*, the thyasirid bivalve *Axinopsida serricata*, and the tanaid *Leptochelia dubia*. The sediments associated with this group were mixed, composed of 16% fines and some coarse black sand with TOC values of 0.4% wt on average.

Table 5.4

Description of cluster groups A–F defined in Figure 5.4. Data for percent fines, total organic carbon (TOC; % weight), depth (m), species richness, and infaunal abundance are expressed as mean values per 0.1-m^2 over all stations in each group. Bold values indicate taxa that were considered most characteristic of that group according to SIMPER analysis (i.e., greatest percentage contribution to within-group similarity).

	Group A	Group B	Group C	Group D	Group E	Group F
n	4	8	9	5	24	4
Percent Fines	2	1	2	8	14	16
Depth	54	30	31	19	27	58
TOC	0.1	0.1	0.1	0.1	0.2	0.4
Species Richness	55	46	45	54	83	111
Abundance	176	502	472	219	376	361
Taxa			**Mean Abundance**			
Mooreonuphis sp SD1	24.3	0.4	3.7			
Spiophanes norrisi	15.1	358.1	324.7	72.0	104.8	8.4
Mooreonuphis sp	11.5	0.6	4.1	0.9	0.1	0.4
Eurydice caudata	10.0	2.1	3.7	0.4	0.2	0.1
Ophiuroconis bispinosa	**10.0**	1.1	3.4		0.6	2.9
Lanassa venusta venusta	7.5	0.1	4.5		0.0	0.1
Euclymeninae sp A	4.5	0.3	0.3	3.0	**19.1**	6.8
Lumbrinerides platypygos	2.3	12.4	4.6	0.1	0.9	
Glycera oxycephala	1.6	**13.4**	1.3	0.8	1.5	0.1
Spio maculata	1.5	1.9	**12.9**		0.0	0.1
Ampharete labrops	0.8	3.1	1.5	**17.3**	2.1	0.4
Aricidea (*Acmira*) *simplex*	0.5		0.1		0.0	**12.6**
Amphiodia urtica	0.1	9.4	2.7	0.1	1.3	8.8
Pista estevanica	0.1	1.1			1.7	8.8
Spiophanes duplex	0.1	0.9	0.2	17.4	17.1	5.3
Monticellina siblina	0.1	0.8	0.1	2.8	17.4	5.8
Notomastus latericeus		12.8	0.3	1.2	4.6	0.5
Dendraster terminalis		**2.5**	**5.7**	2.0	0.0	
Mediomastus sp		0.7		6.6	5.8	2.3
Apoprionospio pygmaea		0.6		5.7	2.3	
Axinopsida serricata					0.3	**12.4**
Myriochele gracilis						29.3

Discussion

Benthic macrofaunal assemblages surrounding the SBOO were similar in 2010 to those encountered during previous years, including the period before initiation of wastewater discharge (City of San Diego 2000, 2010). Additionally, these assemblages were typical of those occurring in other sandy, shallow- and mid-depth habitats throughout the Southern California Bight (SCB) (Thompson et al. 1987, 1993b, City of San Diego 1999, Bergen et al. 2001, Ranasinghe et al. 2003, 2007, Mikel et al. 2007). For example, assemblages from cluster groups B, C and E contained high numbers of the spionid polychaete *Spiophanes norrisi*, a species commonly found in shallow-water environments with sandy sediments in the SCB (Bergen et al. 2001). These three groups represented sub-assemblages of the SCB benthos that differed in the relative abundances of dominant and co-dominant species. Such differences probably reflect variation in sediment structure, such as the presence or absence of red relict sands. Consistent with historical values, sediments in the shallow SBOO region generally were coarser south of the outfall relative to the more northern stations (see Chapter 4).

The group D assemblage contained fewer individuals of *Spiophanes norrisi* relative to the other shallow water groups B, C and E, likely because of the higher percentage of fines found at sites in group D. However, the fewest *S. norrisi* occurred at sites from mid-depth shelf habitats (i.e., cluster groups A and F), probably because these sites represent a transition between the shallow sandy sediments and finer mid-depth sediments characteristic of much of the SCB mainland shelf (Barnard and Ziesenhenne 1961, Jones 1969, Fauchald and Jones 1979, EcoAnalysis et al. 1993, Thompson et al. 1993a, Diener and Fuller 1995). The sediment composition at the sites that make up groups A and F are not typically associated with high *S. norrisi* abundances.

Results from PRIMER analyses revealed no clear spatial patterns relative to the South Bay outfall. Comparisons of the biotic data to the physico-chemical data suggest that macrofaunal distribution and abundance in the region varied primarily along depth and sediment gradients. Populations of *S. norrisi* collected during 2010 were the highest recorded for this polychaete since monitoring began in 1995. Consequently, the high numbers for this species influenced overall abundance values in the region during the past year. Patterns of region-wide abundance fluctuations over time appear to mirror historical patterns of this species, while temporal fluctuations in the populations of this and similar polychaete species (Appendix D.1) occur elsewhere in the region and may correspond to larger scale oceanographic conditions (Zmarzly et al. 1994). Overall, analyses of temporal patterns suggest that the benthic community in the South Bay outfall region has not been significantly impacted by wastewater discharge. For example, while species richness and total macrofaunal abundance were at or near historical highs during 2010, annual means at the four nearfield stations remained similar to those located further away (City of San Diego 2006–2010). Diversity and evenness values have also remained relatively stable since monitoring began in 1995, with some recent exceptions. For example, stations with high *S. norrisi* abundances in 2010 had relatively lower species diversity, evenness, and Swartz dominance values compared to other stations.

Benthic response index (BRI) values continue to be generally characteristic of assemblages from undisturbed habitats. Since monitoring began, mean BRI values at the four nearfield stations have been higher than values for all the farfield stations combined. This pattern has remained consistent over time, including the pre-discharge period. Because this pattern was not affected by the onset of wastewater discharge, it appears that differences in BRI values could be caused by a depth effect inherent with the BRI. For example, Smith et al. (2001) found a pattern of lower index values at mid-depth stations versus shallower or deeper stations.

Anthropogenic impacts are known to have spatial and temporal dimensions that can vary depending on a range of biological and physical factors. Such impacts can be difficult to detect, and specific effects of the SBOO discharge on the local macrobenthic community could not be identified during 2010. Furthermore, benthic invertebrate populations exhibit substantial spatial and temporal variability that may mask the effects of any disturbance event (Morrisey et al. 1992a, b, Otway 1995). Although some changes have occurred near the SBOO over time, benthic assemblages in the area remain similar to those observed prior to discharge and to natural indigenous communities characteristic of similar habitats on the southern California continental shelf.

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